

## ENHANCEMENT OF THE CHANNEL CAPACITY USING MIMO-OFDM TECHNOLOGY FOR WIRELESS TRANSMISSION SYSTEM

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### ABSTRACT

Orthogonal frequency division multiplexing (OFDM) can be used with a multiple-input multiple output (MIMO) system to improve communication quality and capacity. In This paper we shows channel enhancement using MIMO-OFDM technology We analyze the effects of pilot-symbol-aided channel estimation on the lower bound of the system capacity in MIMO-OFDM systems with three different types as well as We derive the optimal pilot-to- data power ratio (PDR) for each of these patterns.

**KEYWORDS:** MIMO, OFDM, MAC, CDMA, PDR, BER, LOS

### INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is one of the most promising physical layer technologies for high data rate wireless communications due to its robustness to frequency selective fading, high spectral efficiency, and low computational complexity. OFDM can be used in conjunction with a multiple-input multiple-output (MIMO) transceiver to increase the diversity gain and/or the system capacity [1], [2], [3], [4]. Because the OFDM system effectively provides numerous parallel narrowband channels, MIMO-OFDM is considered a key technology in emerging high-data rate systems such as 4G, IEEE 802.16, and IEEE 802.11n [5], [6], [7]. In MIMO-OFDM systems, channel state information (CSI) is essential at the receiver in order to coherently detect the received signal and to perform diversity combining or spatial interference suppression. In order to attain instantaneous CSI at the receiver, pilot-symbol-aided or decision-directed channel estimation must be used to track the variations of the frequency selective fading channel [8], [9]. For single-user MIMO channels with perfect transmitter and receiver CSI the ergodic and outage capacity calculations are straightforward since the capacity is known for every channel state. In multiuser channels, capacity becomes a  $d$ -dimensional region defining the set of all rate vectors  $(R_1, R_2, \dots, R_K)$  simultaneously achievable by all  $K$  users. The multiple capacity defamations for time-varying channels under different transmitter and receiver CSI and cm assumptions extend to the capacity region of the multiple-access channel (MAC) and broadcast channel (BC) in the obvious way. However, these MIMO multiuser capacity regions, even for time-invariant channels, are difficult to find. Few capacity results exist for time varying multiuser MIMO channels, especially under the realistic assumption that the transmitter(s) and/or receiver(s) have CDI only. Many practical MIMO techniques have been developed to capitalize on the theoretical capacity gains predicted by Shannon theory. A major focus of such work is space-time coding: recent work in this area is summarized in. Other techniques for MIMO systems include space-time modulation, adaptive modulation and coding, space-time equalization, space-time signal processing, space-time CDMA and space-time OFDM. To date, there have been numerous

previous studies on the problem of optimizing pilot signals for wireless communication systems, but none that optimize the PDR for MIMO-OFDM capacity with comparing various pilot schemes. Optimizing the PDR for DS/CDMA systems has been considered in [10] for the single user case. In multiuser cases, the optimal PDR for the DS/CDMA uplink with multiuser detection has been examined in [11]. Both works optimized the PDR of DS/CDMA systems with respect to the bit error rate (BER) performance. For OFDM systems with a single-input single-output (SISO), optimizing training tones for minimizing the mean square error (MSE) in channel estimates has been proposed in [12], and optimal placement and power of pilot signals for maximizing capacity has been analyzed in [13], [14], and the BER-minimizing pilots for OFDM systems was derived in [15]. For MIMO systems, there have been comparatively fewer studies, but some recent research has begun to develop guidelines for appropriate pilot signal design. For single-carrier MIMO systems, the effects of pilot-assisted channel estimation were analyzed in [16], and an optimal training signal was developed in [17]. Both papers optimize the training signal to maximize the capacity. In [18], the pilot signal is optimized for block transmissions with MIMO systems to maximize the capacity. The problem of optimizing training tones for MIMO-OFDM systems has been addressed in [19]. The metric for optimization in [19] was the MSE of the channel estimation. In this paper, we optimize the PDR of MIMO-OFDM systems by directly maximizing the capacity and show the analysis of the capacity lower bound with the effects of the channel estimation. The analysis shows that the correlation between different channel links in the estimated channel can be removed by using three different pilot patterns which are termed as independent, scattered, and orthogonal, and an optimal PDR is derived for each of those three cases. Our analysis can be viewed as a generalization of prior results on SISO-OFDM [13], as our results reduce to that special case when only one antenna is present at both the transmitter and receiver.

## SYSTEM DESIGN MODEL

It is common to model a wireless channel as a sum of two components, a LOS component and a NLOS component. The Rician factor is the ratio between the power of the LOS component and the mean power of the NLOS component. For MIMO systems, however, the higher the Rician factor  $K$ , the more dominant NLOS becomes. Since NLOS is a time-invariant, it allows high antenna correlation, low spatial degree of freedom, hence, a lower MIMO capacity for the same SNR. In fixed wireless network (macro-cell) MIMO improve the quality of service in areas that are far away from the base station, or are physically limited to using low antennas. In an indoor environment, many simulations and measurements have shown that typically the multipath scattering is rich enough that the LOS component rarely dominates. This plays in favor of in building MIMO deployments (e.g., WLAN).

In the absence of a LOS component, the channel matrix modeled with Gaussian random variables (i.e., Rayleigh fading). The antenna elements can be correlated, often due to insufficient antenna spacing and existence of few dominant scatters. Antenna correlation is considered the leading cause of rank deficiency in the channel matrix, to obtain the highest diversity. In the Rician channel case, the channel matrix can be represented as a sum of the line-of-sight (LOS) and non-line of-sight (NLOS) components

$$H = H_{LOS} + H_{NLOS},$$

$$\text{Where } H_{LOS} \triangleq E\{H\} \text{ and } H_{NLOS} \triangleq H - H_{LOS}.$$

According to this model

$$H_{NLOS}(R_T)^{1/2}H_W(R_R)^{1/2}$$

Where,  $R_R$  is the  $M \times M$  correlation matrix of the receive antennas,  $R_T$  is the  $N \times N$  correlation matrix of the transmit antennas, and  $H_W$  is a complex  $N \times M$  matrix whose elements are zero-mean independent and identically distributed (i. i. d) complex Gaussian random variables. For a MIMO system the channel matrix is written as equation (1)

$$h_{ij} = \alpha + j\beta. \quad (1)$$

### Mathematical Model of MIMO-OFDM

Consider a wireless communication system with  $N_t$  transmit (Tx) and  $N_r$  receive (Rx) antennas. The idea is to transmit different streams of data on the different transmit antennas, but at the same carrier frequency. The stream on the  $p$ -th transmit antenna, as function of the time  $t$ , will be denoted by  $s_p(t)$ . When a transmission occurs, the transmitted signal from the  $p$ -th Tx antenna might find different paths to arrive at the  $q$ -th Rx antenna, namely, a direct path and indirect paths through a number of reflections [4]. For such a system, all the multi-path components between the  $p$ -th Tx and  $q$ -th Rx antenna can be summed up to one term, say  $h_{qp}(t)$ . Since the signals from all transmit antennas are sent at the same frequency, the  $q$ -th receive antenna will not only receive signals from the  $p$ -th, but from all  $N_t$  transmitters. This can be denoted by the following equation (the additive noise at the receiver is omitted for clarity).

$$x_q(t) = \sum_{p=1}^{N_t} h_{qp}(t) s_p(t) \quad (2)$$

To capture all  $N_t$  received signals into one equation, the matrix notation can be used:  $x(t) = H(t)s(t)$ ,

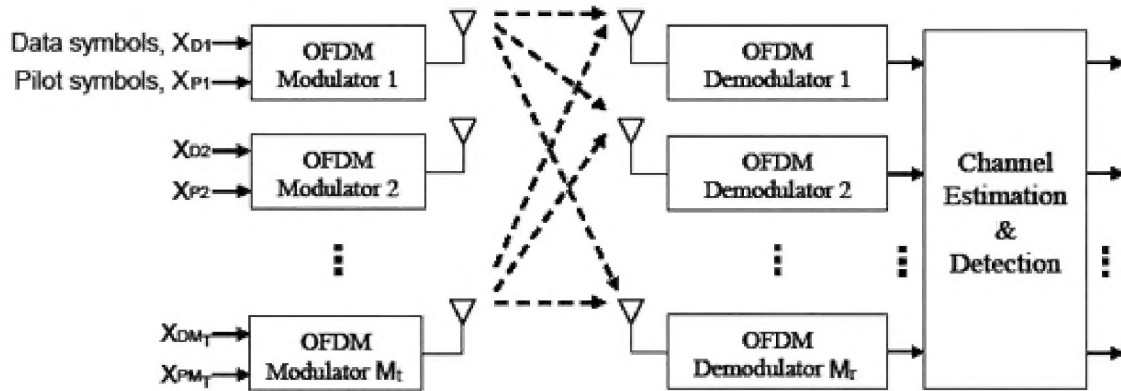


Figure 1: Schematic Representation of a MIMO-OFDM Communication System

where,  $s(t)$  is an  $N_t$  dimensional column vector with  $s_p(t)$  being its  $p$ -th element,  $x(t)$  is  $N_r$ -dimensional with  $x_q(t)$  on its  $q$ -th position and the matrix  $H(t)$  is  $N_r \times N_t$  with  $h_{qp}(t)$  as its  $(q,p)$ -th element, with  $p = 1, \dots, N_t$  and  $q = 1, \dots, N_r$ . A schematic representation of a MIMO communication scheme can be found in Figure 1. Mathematically, a MIMO-OFDM transmission can be seen as a set of equations (the recordings on each Rx antenna) with a number of unknowns (the transmitted signals). If every equation represents a unique combination of the unknown variables and the number of equations is equal to the number of unknowns, then there exists a unique solution to the problem. If the number of equations is larger than the number of unknowns, a solution can be found by performing a projection using the least squares method, also known as the Zero Forcing (ZF) method. For the symmetric case, the ZF solution results in the unique solution.

### Capacity Enhancement Using MIMO

MIMO technologies overcome the deficiencies of these traditional methods through the use of spatial diversity. Data in a MIMO system is transmitted over  $T$  transmit antennas through what is referred to as a "MIMO channel" to  $R$  receive antennas supported by the receiver terminal. This formulation can be easily obtained from the direct use of Eigen value properties. Alternatively, we can decompose the MIMO channel into  $m$  equivalent parallel SISO channels by performing a singular value decomposition (SVD) of [4], [8]. Now that the system model has been established, in this section, we analyze the channel estimation error according to three different pilot patterns to see how the channel estimation error affects the capacity of a MIMO-OFDM system.

The capacity of a 2x2 MIMO-OFDM system with three different pilot patterns according to the percentage of pilot power for 2 different SNR cases (SNR=5,15dB). The case of the perfect channel knowledge allocates the entire transmit power to data symbols and uses 60 subcarriers for data symbols. The capacities of the independent and orthogonal pilot patterns show the same results. At each SNR, the capacity lower bound has maximum value when the percentage of pilot power is about 0.2 for independent and orthogonal cases and about 0.27 for scattered case. This means that we can maximize the capacity by allocating 20% and 27% of the total transmit power to pilot symbols in these cases.

### Capacity with Optimal PDR

The capacity with the optimal PDR in Theorem 1 for 2X2 and 4X4 MIMO-OFDM systems with three different pilot patterns, the capacity of the independent/orthogonal pattern case with the optimal PDR shows higher capacity than the scattered pattern case. It is because we get  $Mt$  gain in pilot SNR when estimating the channel in the independent/orthogonal pattern case and use more subcarriers for data symbols than in the scattered pattern case.

$$\mu = \frac{\text{capacity with PDR}}{\text{capacity with perfect channel knowledge}}$$

This capacity efficiency tells us how much capacity we can get with PDR  $\mu$  when the maximum achievable capacity is the open loop capacity with perfect channel knowledge. We can use this metric to compare the achievable capacity with different PDR.

### SIMULATION RESULTS

The Figure 2 shows the value of the capacity Proportion to SNR respect to the MIMO The largest value the MISO Which in turn is larger than SISO. Also observed that the signal to noise ratio increase when capacity is increase, This linear relationship begin to change gradually when SNR =20 db and SNR=40db respectively, so as to increase the proportion of capacitive increase SNR begins to decline until we get to the SNR= 60 and 80 db Which then becomes The increase in the value of Capacity and very few tend to become fixed value offset by an increase in the value of SNR.

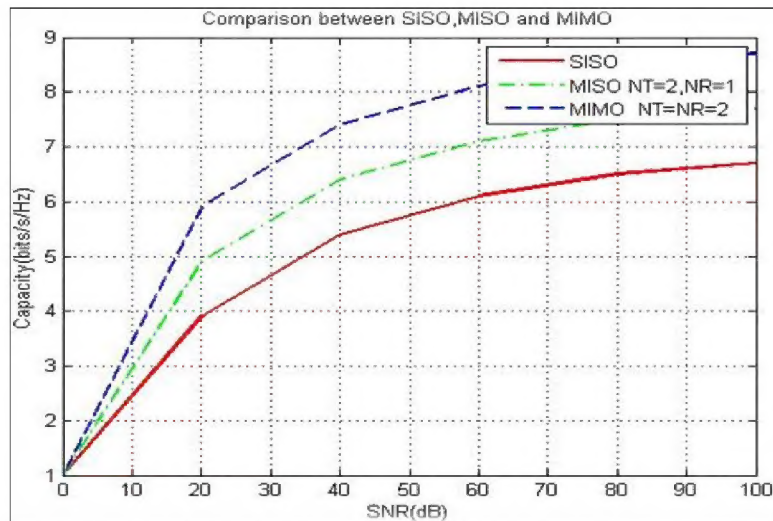


Figure 2: Comparison between SISO, MISO 2x1 and MIMO 2x2

Table 1: Comparison between SISO, MISO and MIMO

System	No. Antenna	SNR in db	Capacity Bits/S/Hz
SISO	1x1	60	6
MISO	2x1	60	7
MIMO	2x2	60	8

We found that the Capacity increased in MISO 2x1 more Than SISO 1x1 at the same SNR value.

We have the now famous capacity equation of MIMO. And the capacity of MIMO 2x2 became more than MISO 2x1 at the same SNR. MIMO technologies overcome the deficiencies of these traditional methods through the use of spatial diversity. Data in a MIMO system is transmitted over T transmit antennas through what is referred to as a "MIMO channel" to R receive antennas supported by the receiver terminal.

### Capacity with Optimal PDR versus SNR

In Figure 3 refers to the capacity with the optimal PDR in Theorem 1 for 2x2, 3x3 and 4x4 MIMO-OFDM systems, In Figure 3 the capacity with the optimal PDR shows higher capacity, It is because we get Mt gain in pilot SNR when estimating the channel. the optimal PDR use more subcarriers for data symbols.

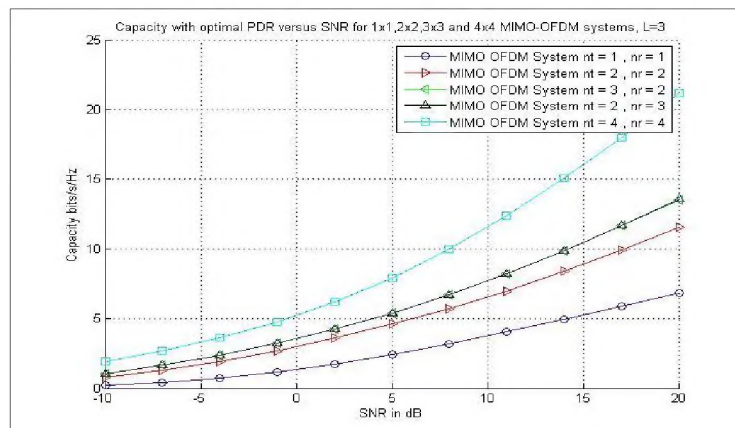


Figure 3: Capacity with Optimal PDR versus SNR for 1x1, 2x2, 3x3 and 4x4 MIMO-OFDM System

**Table 2: Comparison between Capacity with Optimal PDR MIMO-OFDM 1x1, 2x2, 3x2, 2x3, 4x4**

Type of MIMO-OFDM	SNR db	Capacity with Optimal PDR Bits/s/Hz
1x1	20	7
2x2	20	12
3x2	20	13
2x3	20	13
4x4	20	22

From the Table 2 Notes that the higher capacity is 22 bits/s/ Hz when SNR=20 db, when the MIMO –OFDM is 4x4 also.

## CONCLUSIONS

It can be observed from results the capacity lower bound has maximum value when the percentage of pilot power is about 0.2 for independent and orthogonal cases and about 0.27 for scattered case. This means that we can maximize the capacity by allocating 20% and 27% of the total transmit power to pilot symbols in these cases. As future work we reduce the hardware complexity and increase the data rate speed and minimize errors for broadband wireless communication, by introduce various algorithm.

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